Antenna Laboratory
Department of Electrical Engineering
The Ohio State University
1320 Kinnear Road
Columbus, Ohio 43212
6 June 1966

National Aeronautics and Space
Administration
Washington, D.C. 20546

Attn: Code SC
Office of Grants and Research Contracts
Subj: Semi-Annual Status Letter covering
1 December 1965 to 31 May 1966
Grant No. NGR-36-008-048
The Ohio State University Research Foundation
Antenna Laboratory, Project 2143

I. INTRODUCTION

Research has been conducted in two areas during this program interval. These are

(1) the reflection coefficient of a parallel-plate waveguide in the presence of a metallic plate.

(2) the aperture admittance of a circular waveguide radiating into a homogeneous dielectric slab.

II. WORK ACCOMPLISHED

The diffraction by a parallel-plate waveguide aperture with a conducting plate spaced in front of the aperture is being analyzed by means of wedge diffraction theory. The reflection coefficient of the guide (which is the goal of the analysis) is composed of the self-reflection at the aperture and the reflection produced by the plate. The first order reflection from the plate results from the free-space fields of the aperture being reflected back onto the aperture by the plate. The contribution of this reflection to the total reflection coefficient is obtained by integrating the reflected fields across the guide aperture. Results for the reflection coefficient which include the self-reflection and the first order reflection show the effect of guide width and plate spacing on the reflection coefficient. The reflection coefficient as a function of plate spacing is an oscillatory curve caused by the interference of the two components; the oscillations decrease with increasing guide width and increasing plate spacing.

The first order reflected wave results in subsequent diffractions from the guide aperture toward the plate, creating a multiple reflection situation. In the case of the thin-walled guide the second order diffraction of the first order wave is negligible, so that the total reflection coefficient is accurately given by the sum of the self-reflection and the first order reflection from the plate. For the case of waveguide walls formed from non-zero wedge angles subsequent diffractions are significant in many cases.

Examination of the fields of the first order wave for several guide geometries and reflecting plate spacings showed that the wave closely approximates a plane wave insofar as the fields over the aperture are concerned. In general the diffraction by an aperture of this type depends on the fields only near the aperture. Thus it was proposed to treat the second order diffraction from the aperture by approximating it as the diffraction of a plane wave incident upon the aperture. It was also noted that each subsequent diffraction from the aperture would likely be quite similar over the aperture width. At this point it was noted that the sum of all subsequent reflections could be taken into account by application of the Higher Order Diffraction Concept. The total wave diffracted by the aperture is caused by the first-order wave (from the incident wave in the guide) and the resultant superposition of the multiple reflections. By use of this concept the resultant of the multiple reflections can be solved and the total reflection determined. This analysis gives the total reflection coefficient and each of its components: the self-reflection, the first-order reflection from the plate and the resultant of the higher order reflections from the plate. Results which have been obtained from a computer program using this approach show that multiple reflections are significant for wedge angles greater than about 45°.

However, the plane wave analysis of this approach is not accurate for the ground plane case (wedge angles of 90°). In this case the diffraction by the aperture depends on the nature of the incident fields over a much wider region than just that of the guide width. In order to treat this case the cylindrical nature of each reflected wave must be taken into account. Consequently, an analysis was developed in which each order of diffracted wave is treated as that of an incident cylindrical wave. The field and source radius of the incident cylindrical wave is determined from the previous order of diffraction. Thus the computation of this analysis is obtained by using iteration to determine each order of reflection. Preliminary results from this analysis are currently being checked.

Results from these two approaches reveal that for wedge angles in the region of about 70° - 90° the adjacent structure (ground plane) of the guide causes high multiple reflections between the adjacent structure and the conducting plate. This results in large oscillations in the total reflection coefficient as a function of plate spacing. Oscillations of this type are detrimental to good performance as a reflectometer antenna. Thus this analysis demonstrates the significance of the ground plane structure (or adjacent surface of a vehicle on which such an antenna might be mounted) in this application. This type of behavior would be expected for most types of waveguides and low-flare-angle horns mounted in a ground plane.

The aperture admittance of the TE_{11} mode for the circular waveguide covered by a homogeneous dielectric slab is being analyzed. The method of analysis is based on the analysis used for the rectangular waveguide aperture covered by a slab. This analysis employs the variational method in which the form of the fields over the aperture plane are assumed to be that of the incident wave in the guide. The fields outside of the guide are analyzed in terms of their plane wave spectrum; the reflection of each plane-wave component is determined by matching the boundary conditions at the slab. The aperture admittance is thus determined by a numerical integration of the resultant incident and reflected plane wave spectrums. A series of poles occur in the integrand which correspond to the surface waves induced in the slab by the incident wave in the guide. The numerical integration is performed by a computer program which locates the surface-wave poles, evaluates the contributions to the admittance at the poles, and integrates between the poles and in other regions. The integrand is determined by a set of subroutines which essentially compute the plane wave spectrum of the aperture covered by the dielectric slab.

In order to convert the program from computation of the rectangular guide admittance to that for the circular guide, major changes are needed only in the subroutines. The equations have been determined for the plane wave spectrum which matches the TE_{11} circular waveguide mode over the aperture in the ground plane. New subroutines are being written from these equations.

III. PROGRAM FOR NEXT SEMI-ANNUAL PERIOD
(1 June 1966 to 30 November 1966)

The two problems currently under analysis (the parallel-plate guide in presence of a conducting plate and the circular guide aperture covered by a dielectric slab) should be completed in the next program interval. A new area of investigation will be initiated in this program interval: the design of the surfaces of horn walls to reduce multiple reflections. This area should be continued into next year's effort and would be a substantial part of it; thus it is discussed under the proposed program.

After the preliminary results from the program for the parallel-plate guide radiating into a conducting sheet have been sufficiently checked, a more extensive set of results will be obtained. These results should give the specific behavior of the multiple reflections between the ground plane structure and the conducting sheet for this type of waveguide.

The computer subroutines which are being programmed for the calculation of the admittance of the circular guide covered by a dielectric slab will be completed. Computed results will then be obtained for check purposes. Anticipated checks include comparisons with known free-space admittance values, and measurements for various dielectric slabs which will be supplied by NASA.

IV. PROPOSED PROGRAM FOR NEXT CONTRACT YEAR
(1 December 1966 to 30 November 1967)

Two principal areas of investigation are proposed for next year's program. These are

(1) The design of horn wall surfaces to reduce multiple reflections.

(2) Calculation of the reflection coefficient of the conical horn radiating into a conducting sheet.

The results obtained thus far from the parallel-plate waveguide analyses indicate that high multiple reflections will occur for waveguides or low-flare-angle horns which are mounted in typical ground-plane surfaces. This results in large oscillations in the total reflection coefficient, which causes poor performance as a reflectometer antenna. If the ground-plane structure cannot be practically modified, the high multiple reflections between the ground plane and the conducting sheet could be significantly reduced by using wide-flare horns. However, high multiple reflections would probably occur between the horn walls and the conducting sheet. During the next program interval the design of horns and horn wall surfaces will be investigated to minimize multiple reflections for wide-flare horns. Specifically the use of surface wave trapping of the first order reflection appears promising to minimize higher order reflections. Dielectric sheets and corrugated surfaces will be designed and tested on the walls of small horn models.

The reflection coefficient of the conical horn can be calculated by means of aperture integration techniques. The results of such computations would be used to determine the influence of flare angle and aperture size on multiple reflections. Also, these computations would give specific reflectometer performance for the types of antennas used in actual flight tests. The goal of this study would be to determine good horn designs for minimization of multiple reflections. This basic horn design information would be combined with the use of appropriate horn wall surfaces to yield a good overall reflectometer antenna design.